BIOLOGICAL INTEGRITY OF THE YAAK RIVER AND THE WEST FORK YAAK RIVER BASED ON THE STRUCTURE AND COMPOSITION OF THE BENTHIC ALGAE COMMUNITY

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Summary

In August 2003, periphyton samples were collected from 3 sites on the Yaak River and 1 site on the West Fork of the Yaak River in northwestern Montana for the purpose of assessing whether these streams are water-quality limited and in need of TMDLs. The samples were collected following MDEQ standard operating procedures, processed and analyzed following standard methods for periphyton, and evaluated following modified USEPA rapid bioassessment protocols for wadeable streams.

An unusually large percentage of the pollution-tolerant species *Synedra rumpens* and a large percentage of abnormal diatom cells suggest **moderate impairment by heavy metals** in the West Fork of the Yaak River. There are no known sources of heavy metals in the West Fork drainage. The West Fork site also had the lowest diatom species richness, diatom species diversity, and pollution index values of all four sites that were sampled in the Yaak. Values for these metrics indicated minor impairment.

Diatom metrics suggest that the three sites on the main Yaak River were subject to minor stress from unknown causes. All three sites supported a small number of abnormal diatom cells and the Whitetail Camp Ground and Sylvanite sites had elevated values for the disturbance index. Paralleling a downstream increase in abundance of pollution-tolerant algae, the pollution index declined in a downstream direction but remained above the criterion for minor impairment at all three sites. The siltation index peaked at Whitetail Camp Ground but remained just below the threshold for minor impairment. Values for the diatom species diversity index also declined in a downstream direction.

The sample from Sylvanite was dominated by cells and polysaccharide stalks of the diatom *Didymosphenia geminata*. Colonies of this diatom look like dirty cotton balls. This is a widespread boreal species that is often reported to produce nuisance standing crops in northern streams of Europe and North America.

Introduction

This report evaluates the biological integrity[1], support of aquatic life uses, and probable causes of stress or impairment to aquatic communities in the Yaak River and the West Fork of the Yaak River in northwestern Montana. The purpose of this report is to provide information that will help the State of Montana determine whether these streams are water-quality limited and in need of TMDLs.

The federal Clean Water Act directs states to develop water pollution control plans (Total Maximum Daily Loads or TMDLs) that set limits on pollution loading to water-quality limited waters. Water-quality limited waters are lakes and stream segments that do not meet water-quality standards, that is, that do not fully support their beneficial uses. The Clean Water Act and USEPA regulations require each state to (1) identify waters that are water-quality limited, (2) prioritize and target waters for TMDLs, and (3) develop TMDL plans to attain and maintain water-quality standards for all water-quality limited waters.

Evaluation of aquatic life use support in this report is based on the species composition and structure of periphyton (benthic algae, phytobenthos) communities at four sites that were sampled in August of 2003. Periphyton is a diverse assortment of simple photosynthetic organisms called algae that live attached to or in close proximity of the stream bottom. Some algae form long filaments or large gelatinous colonies that are conspicuous to the unaided eye. But most algae, including the ubiquitous diatoms, can be seen and identified only with the aid of a microscope. The periphyton community is a basic biological component of all aquatic ecosystems. Periphyton accounts for much of the primary production and biological diversity in Montana streams (Bahls et al. 1992). Plafkin et al. (1989) and Barbour et al. (1999) list several advantages of using periphyton in biological assessments.

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[1] *Biological integrity* is defined as "the ability of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats within a region" (Karr and Dudley 1981).

Project Area and Sampling Sites

The project area is located within the Northern Rockies Ecoregion in Lincoln County, Montana. The mountains and valleys of the Northern Rockies are covered by extensive Douglas-fir and subalpine fir climax forests. Portions of it are influenced by moist maritime air masses and support Pacific Coast trees such as western hemlock and western redcedar. Alpine areas occur but, as a whole, the region has lower elevations, less perennial snow and ice, and fewer glacial lakes than the adjacent Canadian Rockies. Logging and mining are common and have affected water quality. Recreational uses are also important (Woods et al. 1999).

Periphyton samples were collected at three sites on the Yaak River and one site on the West Fork of the Yaak River (Table 1). The Yaak River is a tributary of the Kootenai River and occupies USGS HUC 17010103. Waters in the Yaak River basin are classified B-1 in the Montana Surface Water Quality Standards.

Methods

Periphyton samples were collected following standard operating procedures of the MDEQ Planning, Prevention, and Assistance Division. Using appropriate tools, microalgae were scraped, brushed, or sucked from natural substrates in proportion to the importance of those substrates at each study site. Macroalgae were picked by hand in proportion to their abundance at each site. All collections of microalgae and macroalgae were pooled into a common container and preserved with Lugol's (IKI) solution.

The samples were examined to estimate the relative abundance of cells and rank by biovolume of diatoms and genera of soft (non-diatom) algae according to the method described by Bahls (1993). Soft algae were identified using Smith (1950), Prescott (1962, 1978), John et al. (2002), and Wehr and Sheath (2003). These books also served as references on the ecology of the soft algae, along with Palmer (1969, 1977).

After the identification of soft algae, the raw periphyton samples were cleaned of organic matter using sulfuric acid, potassium dichromate, and hydrogen peroxide. Then permanent diatom slides were prepared using Naphrax™, a high refractive index mounting medium, following *Standard Methods for the Examination of Water and Wastewater* (APHA 1998). At least 300 diatom cells (600 valves) were counted at random and identified to species. The following were the main taxonomic references for the diatoms: Krammer and Lange-Bertalot 1986, 1988, 1991a, 1991b; Lange-Bertalot 1993, 2001; Krammer 1997a, 1997b, 2002; Reichardt 1997, 1999. Where applicable, conventions for diatom nomenclature followed those adopted by the Integrated Taxonomic Information System (http://www.itis.usda.gov). For taxa not included in ITIS, naming conventions followed those adopted by the Academy of Natural Sciences for USGS NAWQA samples (Morales and Potapova 2000). Van Dam et al. (1994) was the main ecological reference for the diatoms.

The diatom proportional counts were used to generate an array of diatom association metrics. A metric is a characteristic of the biota that changes in some predictable way with increased human influence (Barbour et al. 1999). Diatoms are particularly useful in generating metrics because there is a wealth of information available in the literature regarding the pollution tolerances and water quality preferences of common diatom species (e.g., Lowe 1974, Beaver 1981, Lange-Bertalot 1996, Van Dam et al. 1994).

Values for selected metrics were compared to biocriteria (numeric thresholds) developed for streams in the Rocky Mountain ecoregions of Montana (Table 2). These criteria are based on metric values measured in least-impaired reference streams (Bahls et al. 1992) and metric values measured in streams that are known to be impaired by various sources and causes of pollution (Bahls 1993). The criteria in Table 2 are valid only for samples collected during the summer field season (June 21-September 21) and distinguish among four levels of stress or impairment and three levels of aquatic life use support: (1) no impairment or only minor impairment (full support); (2) moderate impairment (partial support); and (3) severe impairment (nonsupport). These impairment levels correspond to excellent, good, fair, and poor biological integrity, respectively. In cold, high-gradient mountain streams, natural stressors will often mimic the effects of man-caused impairment on some metric values.

Quality Assurance

Several steps were taken to assure that the study results are accurate and reproducible. Upon receipt of the samples, station and sample attribute data were recorded in the Montana Diatom Database and the samples were assigned a unique number, e.g., 3332-01. The first part of this number (3332) designates the sampling site (West Fork Yaak River, upper) and the second part (01) designates the number of periphyton samples that that have been collected at this site for which data have been entered into the Montana Diatom Database.

Sample observations and analyses of soft (non-diatom) algae were recorded in a lab notebook along with information on the sample label. A portion of the raw sample was used to make duplicate diatom slides. The slides used for the diatom proportional counts will be deposited in the Montana Diatom Collection at the University of Montana Herbarium (MONTU) in Missoula. Duplicate slides will be retained in the offices of *Hannaea* in Helena, Montana. Diatom proportional counts have been entered into the Montana Diatom Database.

Results and Discussion

Results are presented in Tables 3, 4 and 5 and Figures 1 and 2, which are located near the end of the report following the references section. Appendix A contains a diatom report for each sample. Each diatom report includes an alphabetical list of diatom species in that sample and their percent abundances, and values for 65 different diatom metrics and ecological attributes.

Sample Notes

Yaak River above East Fork. This sample was moldy and consisted mostly of moss and macrophytes. The *Stigeoclonium* in this sample was senescent.

Yaak River at Whitetail Campground. This sample contained moss. Diatom biomass was composed mostly of the polysaccharide stalks of a large *Cymbella* species. Two species of *Oedogonium* were present.

Yaak River at Sylvanite. This sample consisted of a large gray mass ("dirty cotton ball") that was composed mostly of the polysaccharide stalks of the diatom *Didymosphenia geminata*.

West Fork Yaak River. This sample was virtually free of sediment. Both the chantransia stage and the usual vegetative stage of *Batrachospermum* were included in the sample. The *Ulothrix* in this sample was not *U. zonata*.

Non-Diatom Algae (Table 3)

Yaak River above East Fork. Diatoms were the most abundant group of algae at this site, followed by several genera of green algae. *Stigeoclonium*, a pollution tolerant and branched filamentous green alga, was frequent here and ranked second after diatoms in biovolume. The encrusting brown alga *Heribaudiella* ranked seventh in biovolume here. This alga is typically found only in cold and clean mountain streams. Altogether, this site supported nine genera of non-diatom algae representing two algal divisions. This was the only site where cyanobacteria (blue-green algae) were absent.

Yaak River at Whitetail Campground. Diatoms dominated the sample from this site, followed by 9 genera of green algae. The most common green algae were *Spirogyra* ("pond scum"), *Scenedesmus, Oedogonium, Chaetophora,* and *Cosmarium*. The only cyanobacterium was *Merismopedia*, which was rare. This site supported 10 genera of non-diatom algae representing two algal divisions.

Yaak River at Sylvanite. Diatoms also dominated the sample from this site, followed in biovolume rank by the pollution tolerant *Stigeoclonium*, which was abundant. A few other green

algae and one genus of cyanobacteria (*Anabaena*) accounted for a small portion of the sample's biomass. This site supported the smallest number of non-diatom genera (6) of all the sites.

West Fork Yaak River. The periphyton community at this site was dominated by the filamentous red alga *Batrachospermum*. This is a diverse and widespread genus in North America. In Montana, *Batrachospermum* is found mostly in small, cold mountain streams in the northwest part of the state. After *Batrachospermum* and diatoms, which ranked second in biovolume, the West Fork sample was composed mostly of filamentous green algae (*Spirogyra, Hormidium, Microspora,* and *Mougeotia*). Fourteen genera of non-diatom algae, representing three algal divisions, were found in the sample from the West Fork (Table 3). This is excellent algal diversity for a mountain stream.

Diatoms (Table 4, Figures 1 and 2)

The 15 major diatom species from the Yaak River and the West Fork of the Yaak River are included in pollution tolerance classes 3 and 2 and are either sensitive to organic pollution or only somewhat tolerant of organic pollution (Table 4). None of the major diatom species in these streams are most tolerant of organic pollution (pollution tolerance class = 1).

Yaak River above East Fork. A few abnormal diatom cells indicate possible minor stress on the periphyton community at this site. All other diatom metrics indicate no stress, excellent biological integrity, and full support of aquatic life uses. The dominant diatom species here—*Cocconeis placentula* and *Achnanthidium minutissimum*—are attached species that are resistant to disturbance and sensitive to organic pollution. Although the siltation index was well below the threshold for minor impairment, one of the major species at this site (*Planothidium lanceolatum*) is adapted to living on sand grains. This site exhibited the best diatom diversity, the least organic loading, and the least disturbance of the 3 Yaak River sites (Figures 1 and 2).

Yaak River at Whitetail Campground. The percent *Achnanthidium minutissimum* (disturbance index), percent dominant species, and percent abnormal cells at this site indicate minor stress from unknown sources. Other diatom metrics indicate no stress, excellent biological integrity, and full support of aquatic life uses. However, the siltation index at this site approached (but did not exceed) the threshold for minor impairment and the pollution index was smaller than it was above the East Fork, which indicates an increase in organic loading. The decline in the pollution index was due to increases in abundance of pollution tolerant species, primarily *Synedra rumpens* and *Synedra ulna.* This site shared 41% of its diatom assemblage with the site above the East Fork, which indicates that a minor to moderate change in overall environmental conditions occurred between these sites.

Yaak River at Sylvanite. *Achnanthidium minutissimum* accounted for over 41 percent of the diatom cells at this site, which indicates minor disturbance. The cause of this disturbance is unknown and may be physical, chemical, or biological in origin. About 1% of the diatom cells here were abnormal, but this value is within the range of minor impairment. The cause of these abnormal cells is unknown. Other metrics indicate no impairment and full support of aquatic life uses. However, diatom species richness and diversity were significantly lower here than they were upstream (Table 4, Figure 1). The pollution index was about the same as it was at Whitetail Camp Ground and the siltation index was intermediate between the low value above the East Fork and the high value at Whitetail Camp Ground. Although numerically insignificant, the very large cells of *Didymosphenia geminata* and their polysaccharide stalks accounted for most of the biomass at this site. *D. geminata* is a boreal species that often produces large standing crops in streams. This site shared 52% of its diatom assemblage with the Whitetail site, which indicates a minor change in environmental conditions and diatom species composition.

West Fork Yaak River. The large percentage of *Synedra rumpens* (63.12%) and the much larger than usual percentage of abnormal diatom cells (4.77%) each indicates **moderate impairment and only partial support of aquatic life uses** at this site. *Synedra rumpens* tolerates some organic enrichment as well as elevated concentrations of heavy metals. Diatom species richness and diversity were very low here (Table 4 and Figure 1). All of these metrics suggest toxicity from heavy metals. Although this site supported a relatively large number of

non-diatom genera, it had the lowest diatom species richness and diversity values, the lowest siltation index and pollution index values, and the largest percent dominant species and percent abnormal cells of all four sites (Table 4, Figures 1 and 2). There are no known sources of heavy metals in the West Fork drainage (Tina Laidlaw, USEPA, personal communication).

Modal Categories (Table 5)

Several ecological attributes assigned by Stevenson (digital communication) and Van Dam et al. (1994) were selected from the diatom reports in the appendix and modal categories of these attributes were extracted to characterize water quality tendencies in the Yaak River and the West Fork of the Yaak River (Table 5).

Most diatoms at the upper two sites on the Yaak River are non-motile freshwater autotrophs that prefer pH values >7, continuously high concentrations of dissolved oxygen, a moderate amount of organic loading, and variable concentrations of inorganic nutrients. At Sylvanite, the modal categories were the same except that most diatoms here preferred pH values of about 7 (circumneutral).

The modal category for pH was also circumneutral in the West Fork of the Yaak River. The modal category for trophic state in the West Fork was oligo-mesotraphentic, which indicates smaller concentrations of inorganic nutrients than in the main Yaak River. The modal categories for nitrogen uptake, oxygen demand, and saprobity were "not classified" in the West Fork. This is because the ecological affinities of the dominant species (*Synedra rumpens*) in the West Fork are unknown for these three environmental attributes.

References

APHA. 1998. Standard Methods for the Examination of Water and Wastewater. 20th Edition. American Public Health Association, Washington, D.C.

Bahls, L.L. 1979. Benthic diatom diversity as a measure of water quality. Proceedings of the Montana Academy of Sciences 38:1-6.

Bahls, L.L. 1993. Periphyton Bioassessment Methods for Montana Streams (revised). Montana Department of Health and Environmental Sciences, Helena.

Bahls, L.L., Bob Bukantis, and Steve Tralles. 1992. Benchmark Biology of Montana Reference Streams. Montana Department of Health and Environmental Sciences, Helena.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use In Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish. Second Edition. EPA/841-B-99-002. U.S. Environmental Protection Agency, Office of Water, Washington, D.C.

Beaver, Janet. 1981. Apparent Ecological Characteristics of Some Common Freshwater Diatoms. Ontario Ministry of The Environment, Technical Support Section, Don Mills, Ontario.

Hieber, Maggi, C.T. Robinson, S. R. Rushforth, and Urs Uehlinger. 2001. Algal communities associated with different alpine stream types. Arctic, Antarctic, and Alpine Research 33(4):447-456.

Johansen, J.R. 1999. Diatoms of Aerial Habitats. Chapter 12 *in* Stoermer, E.F., and J.P. Smol (eds.), The Diatoms: Applications For the Environmental and Earth Sciences, Cambridge University Press, New York.

John, D.M., B.A. Whitton, and A.J. Brook (eds.). 2002. The Freshwater Algal Flora of the British Isles: An Identification Guide to Freshwater and Terrestrial Algae. Cambridge University

Karr, J.R., and D.R. Dudley. 1981. Ecological perspectives on water quality goals. Environmental Management 5:55-69.

Kawecka, B. 1990. The effect of flood-control regulation of a montane stream on the communities of sessile algae. Acta Hydrobiology 32:345-354.

Krammer, Kurt. 1997a. Die cymbelloiden Diatomeen: Eine Monographie der weltweit bekannten Taxa. Teil 1. Allgemeines and *Encyonema* Part. J. Cramer, Berlin.

Krammer, Kurt. 1997b. Die cymbelloiden Diatomeen: Eine Monographie der weltweit bekannten Taxa. Teil 2. *Encyonema* part., *Encyonopsis* and *Cymbellopsis*. J. Cramer, Berlin.

Krammer, Kurt. 2002. *Cymbella*. Volume 3 in Diatoms of Europe, Horst Lange-Bertalot, ed. A.R.G. Gantner Verlag K.G., Germany.

Krammer, K., and H. Lange-Bertalot. 1986. Bacillariophyceae, Part 2, Volume 1: Naviculaceae. In Ettl, H., J Gerloff, H. Heynig, and D. Mollenhauer (eds.), Freshwater Flora of Middle Europe. Gustav Fischer Publisher, New York.

Krammer, K., and H. Lange-Bertalot. 1988. Bacillariophyceae, Part 2, Volume 2: Bacillariaceae, Epithemiaceae, Surirellaceae. In Ettl, H., J. Gerloff, H. Heynig, and D. Mollenhauer (eds.), Freshwater Flora of Middle Europe. Gustav Fischer Publisher, New York.

Krammer, K., and H. Lange-Bertalot. 1991a. Bacillariophyceae, Part 2, Volume 3: Centrales, Fragilariaceae, Eunotiaceae. In Ettl, H., J. Gerloff, H. Heynig, and D. Mollenhauer (eds.), Freshwater Flora of Middle Europe. Gustav Fischer Publisher, Stuttgart.

Krammer, K., and H. Lange-Bertalot. 1991b. Bacillariophyceae, Part 2, Volume 4: Achnanthaceae, Critical Supplement to *Navicula* (Lineolatae) and *Gomphonema*, Complete List of Literature for Volumes 1-4. In Ettl, H., G. Gartner, J. Gerloff, H. Heynig, and D. Mollenhauer (eds.), Freshwater Flora of Middle Europe. Gustav Fischer Publisher, Stuttgart.

Lange-Bertalot, Horst. 1979. Pollution tolerance of diatoms as a criterion for water quality estimation. Nova Hedwigia 64:285-304.

Lange-Bertalot, Horst. 1993. 85 new taxa and much more than 100 taxonomic clarifications supplementary to Susswasserflora von Mitteleuropa Vol. 2/1-4. J. Cramer, Berlin.

Lange-Bertalot, Horst. 1996. Rote Liste der limnischen Kieselalgen (Bacillariophyceae) Deutschlands. Schr.-R. f. Vegetationskde., H. 28, pp. 633-677. BfN, Bonn-Bad Godesberg.

Lange-Bertalot, Horst. 2001. *Navicula sensu stricto*: 10 Genera Separated from *Navicula sensu lato; Frustulia.* Volume 2 in Diatoms of Europe, Horst Lange-Bertalot, ed. A.R.G. Gantner Verlag K.G., Germany.

Lowe, R.L. 1974. Environmental Requirements and Pollution Tolerance of Freshwater Diatoms. EPA-670/4-74-005. U.S. Environmental Protection Agency, National Environmental Research Center, Office of Research and Development, Cincinnati, Ohio.

McFarland, B.H., B.H. Hill, and W.T. Willingham. 1997. Abnormal *Fragilaria* spp. (Bacillariophyceae) In streams impacted by mine drainage. Journal of Freshwater Ecology 12(1):141-149.

Morales, E.A., and Marina Potapova. 2000. Third NAWQA Workshop on Harmonization of Algal Taxonomy, May 2000. Patrick Center for Environmental Research, The Academy of Natural Sciences, Philadelphia.

Nicholls, K.H., and D.E.Wujek. 2003. Chrysophycean Algae. Chapter 12 (pp. 471-509) *in* Wehr, J.D., and R.G. Sheath (eds.), Freshwater Algae of North America: Ecology and Classification. Academic Press, New York.

Palmer, C.M. 1969. A composite rating of algae tolerating organic pollution. Journal of Phycology 5:78-82.

Palmer, C.M. 1977. Algae and Water Pollution: An Illustrated Manual on the Identification, Significance, and Control of Algae in Water Supplies and in Polluted Water. EPA-600/9-77-036.

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. 1989. Rapid Bioassessment Protocols for Use in Rivers and Streams: Benthic Macroinvertebrates and Fish. EPA 440-4-89-001.

Prescott, G.W. 1962. Algae of the Western Great Lakes Area. Wm. C. Brown Company, Dubuque, Iowa.

Prescott, G.W. 1978. How to Know the Freshwater Algae. Third Edition. Wm. C. Brown Company Publishers, Dubuque, Iowa.

Reichardt, Erwin. 1997. Taxonomische Revision des Artenkomplexes um *Gomphonema pumilum* (Bacillariophyta). Nova Hedwigia 65(1-4) :99-129.

Reichardt, Erwin. 1999. Zur Revision der Gattung *Gomphonema*. A.R.G. Gantner Verlag, Distributed by Koeltz Scientific Books, Konigstein, Germany.

Renfro, H.B., and D.E. Feray. 1972. Geological Highway Map of the Northern Rocky Mountain Region. American Association of Petroleum Geologists, Tulsa, Oklahoma.

Smith, G.M. 1950. The Fresh-Water Algae of The United States. McGraw-Hill Book Company, New York.

Stevenson, R.J., and Y. Pan. 1999. Assessing Environmental Conditions in Rivers and Streams with Diatoms. Chapter 2 *in* Stoermer, E.F., and J.P. Smol (eds.), The Diatoms: Applications For the Environmental and Earth Sciences, Cambridge University Press, New York.

Stewart, W.D.P., P. Rowell, and A.N. Rai. 1980. Symbiotic Nitrogen-Fixing Cyanobacteria. Pp. 239-277 in Stewart, W.D.P., and J. Gallo (eds.), Nitrogen Fixation, Academic Press, New York.

USDA. 1976. Climax Vegetation of Montana (map). U.S. Department of Agriculture, Soil Conservation Service, Cartographic Unit, Portland.

USEPA. 2000. Level III Ecoregions of the Continental United States (map). National Health and Environmental Effects Research Laboratory, U.S. Environmental Protection Agency, Corvallis, Oregon.

Van Dam, Herman, Adrienne Mertens, and Jos Sinkeldam. 1994. A coded checklist and ecological Indicator values of freshwater diatoms from The Netherlands. Netherlands Journal of Aquatic Ecology 28(1):117-133.

Weber, C.I. (ed.). 1973. Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents. EPA-670/4-73-001. U.S. Environmental Protection Agency, National Environmental Research Center, Office of Research and Development, Cincinnati, Ohio.

Wehr, J.D., and R.G. Sheath. 2003. Freshwater Algae of North America: Ecology and Classification. Academic Press, New York.

Whittaker, R.H. 1952. A study of summer foliage insect communities in the Great Smoky Mountains. Ecological Monographs 22:1-44.

Woods, A.J., Omernik, J.M., Nesser, J.A., Shelden, J., and S.H. Azevedo. 1999. Ecoregions of Montana (color poster with map), U.S. Geological Survey, Reston, Virginia.

Figure 1. Diatom diversity index, pollution index, and % abnormal cells in periphyton samples collected from the Yaak River and West Fork Yaak River in 2003.

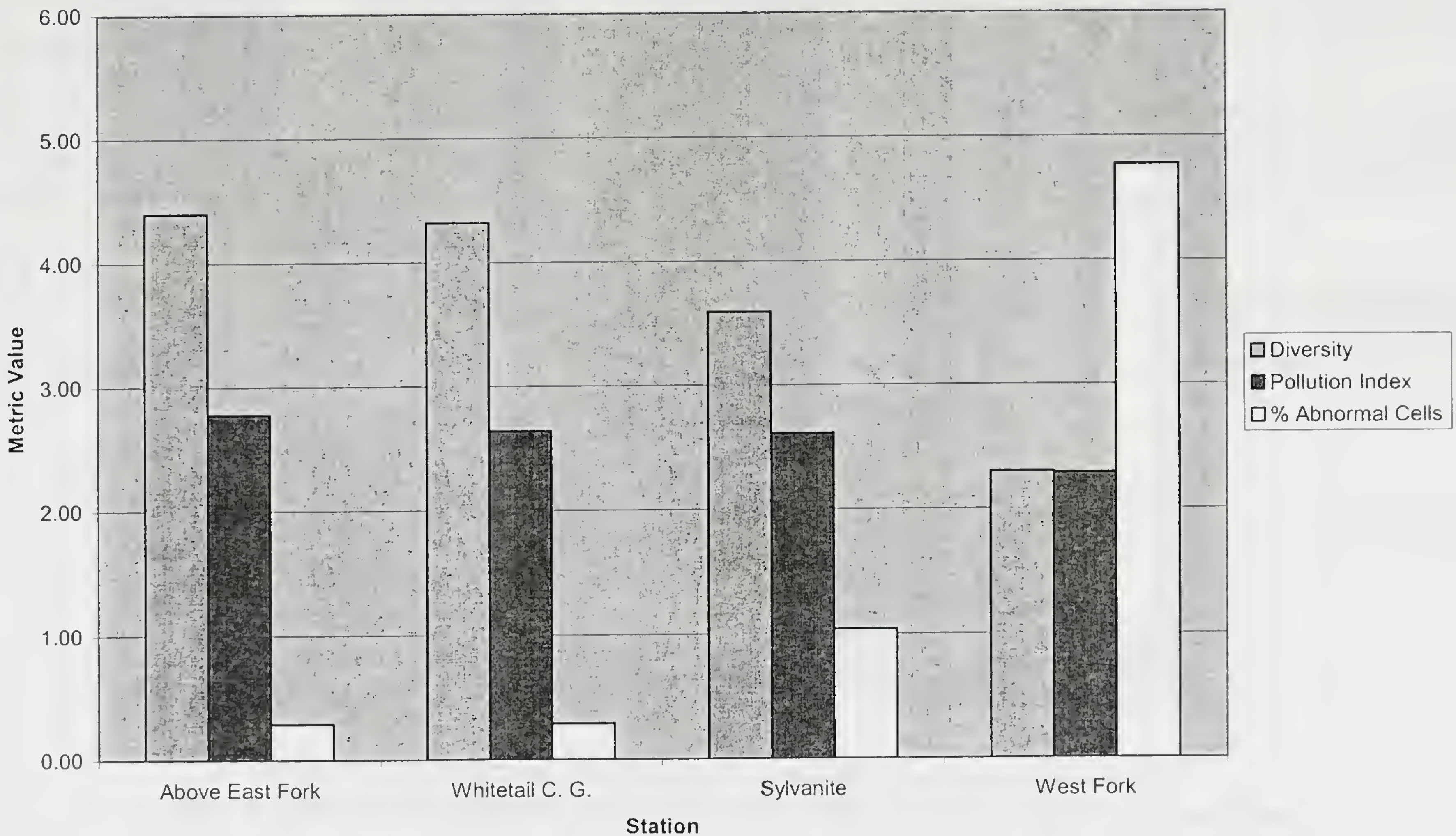

Figure 2. Diatom siltation index, disturbance index, and % dominant species in periphyton samples collected from the Yaak River and West Fork Yaak River in 2003.

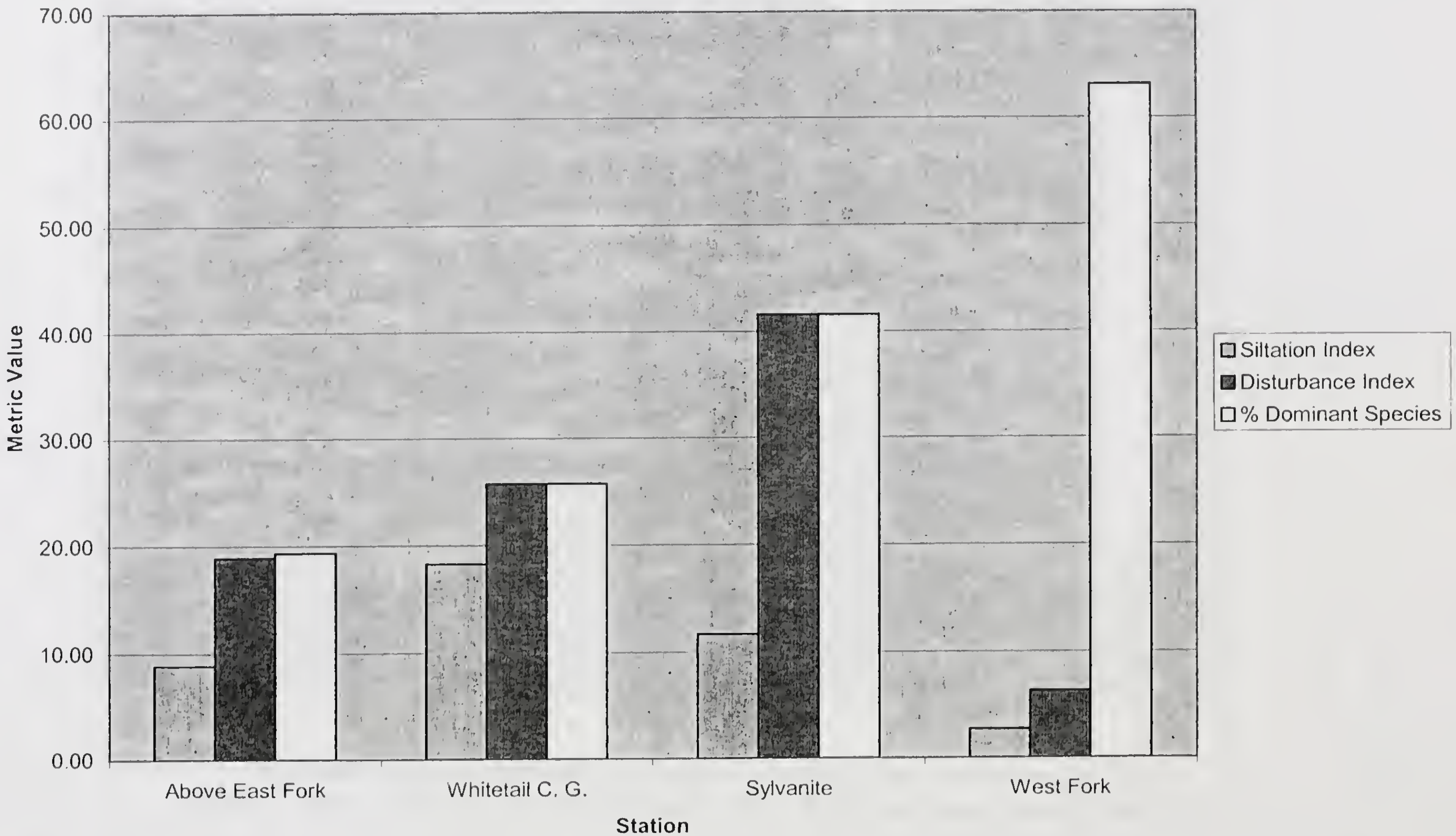

Table 1. Location of periphyton sampling stations in the Yaak River TMDL Planning Area, 2003.

Stream Name and Location	MDEQ Sample Code	Hannaea Sample Code	Latitude	Longitude	Sample Date
Yaak River above East Fork	K03YAAKR01	3084-01	48 57 00	115 36 36	8/14/03
Yaak River at Whitetail Campground	K03YAAKR02	3085-01	48 49 48	115 47 24	8/15/03
Yaak River at Sylvanite	K03YAAKR03	3086-01	48 43 12	115 52 12	8/16/03
West Fork Yaak River	K03YAKWR01	3332-01	48 55 48	115 54 36	8/16/03

Table 2. Diatom association metrics used by the State of Montana to evaluate biological integrity in **mountain** streams: references, range of values, expected response to increasing impairment or natural stress, and criteria for rating levels of biological integrity. The lowest rating for any one metric is the rating for that site.

Biological Integrity/ Impairment or Stress/ Use Support	No. of Species Counted[1]	Diversity Index (Shannon)	Pollution Index[3]	Siltation Index[4]	Disturbance Index[5]	% Dominant Species[6]	% Abnormal Cells[7]	Similarity Index[8]
Excellent/None Full Support	>29	>2.99	>2.50	<20.0	<25.0	<25.0	0	>59.9
Good/Minor Full Support	20-29	2.00-2.99	2.01-2.50	20.0-39.9	25.0-49.9	25.0-49.9	>0.0, <3.0	40.0-59.9
Fair/Moderate Partial Support	19-10	1.00-1.99	1.50-2.00	40.0-59.9	50.0-74.9	50.0-74.9	3.0-9.9	20.0-39.9
Poor/Severe Nonsupport	<10	<1.00	<1.50	>59.9	>74.9	>74.9	>9.9	<20.0
References	Bahls 1979 Bahls 1993	Bahls 1979	Bahls 1993	Bahls 1993	Barbour et al. 1999	Barbour et al. 1999	McFarland et al. 1997	Whittaker 1952
Range of Values	0-100+	0.00-5.00+	1.00-3.00	0.0-90.0+	0.0-100.0	~5.0-100.0	0.0-30.0+	0.0-100.0
Expected Response	Decrease[9]	Decrease[9]	Decrease	Increase	Increase	Increase	Increase	Decrease

[1]Based on a proportional count of 300 cells (600 valves)
[2]Base 2 [bits] (Weber 1973)
[3]Composite numeric expression of the pollution tolerances assigned by Lange-Bertalot (1979) to the common diatom species
[4]Sum of the percent abundances of all species in the genera *Navicula, Nitzschia* and *Surirella*
[5]Percent abundance of Achnanthidium minutissimum (synonym: *Achnanthes minutissima*)
[6]Percent abundance of the species with the largest number of cells in the proportional count
[7]Cells with an irregular outline or with abnormal ornamentation, or both
[8]Percent Community Similarity (Whittaker 1952)
[9]Species richness and diversity may increase somewhat in mountain streams in response to slight to moderate increases in nutrients or sediment

Table 3. Relative abundance of cells and ordinal rank by biovolume of diatoms (Division Bacillariophyta) and genera of non-diatom algae in periphyton samples collected from the Yaak River TMDL Planning Area in 2003.

Taxa	Yaak River Above East Fork	Yaak River at Whitetail C. G.	Yaak River at Sylvanite	West Fork Yaak River
Cyanophyta (blue-greens)				
Anabaena			occasional/6th	
Merismopedia		rare/11th		
Phormidium				common/8th
Rhodophyta (red algae)				
Batrachospermum				dominant/1st
Chlorophyta (green algae)				
Ankistrodesmus	common/6th	common/9th	common/3rd	occasional/15th
Botryococcus	rare/10th			
Chaetophora		common/5th		
Closteriopsis			rare/7th	
Closterium		occasional/10th		common/7th
Cosmarium		common/6th		occasional/12th
Hormidium				frequent/4th
Microspora				frequent/5th
Mougeotia	common/3rd	occasional/7th		common/6th
Netrium				occasional/11th
Oedogonium		common/4th		
Pediastrum	rare/9th	occasional/8th	occasional/4th	
Scenedesmus	common/5th	frequent/3rd	occasional/5th	
Spirogyra	occasional/4th	frequent/2nd		frequent/3rd
Staurastrum	occasional/8th			occasional/13th
Stigeoclonium	frequent/2nd		abundant/2nd	rare/14th
Ulothrix				occasional/10th
Zygnema				occasional/9th
Phaeophyta (brown algae)				
Heribaudiella	occasional/7th			
Bacillariophyta (diatoms)	abundant/1st	dominant/1st	dominant/1st	abundant/2nd
No. Non-Diatom Genera	9	10	6	14

Table 4. Percent abundance of major diatom species[1] and values of selected diatom association metrics for periphyton samples collected from the Yaak River TMDL Planning Area in 2003. Underlined values indicate minor stress; **bold values** indicate moderate stress; **underlined and bold** values indicate severe stress; all other values indicate no stress and full support of aquatic life uses when compared to biocriteria (thresholds) in Table 2. Observed stress may be natural or anthropogenic.

Species/Metric	PTC[2]	Yaak River Above East Fork	Yaak River at Whitetail C. G.	Yaak River at Sylvanite	West Fork Yaak River
Achnanthidium minutissimum	3	18.92	25.77	41.59	6.36
Cocconeis placentula	3	19.36	1.02	0.30	
Cymbella muelleri	2		0.44	5.41	
Encyonema minutum	2		3.22	0.60	
Encyonopsis subminuta	2	2.77	3.81	2.40	
Fragilaria capucina	2	4.66	0.88	12.31	1.27
Gomphonema pumilum	3	7.71	0.29	0.30	
Hannaea arcus	3	0.29	0.59	3.45	10.49
Navicula cryptotenella	2		2.20	3.00	
Nitzschia bryophila	3		3.66	1.20	
Nitzschia lacuum	3	0.29	3.95	0.30	
Planothidium lanceolatum	2	4.66	0.88		
Staurosira construens	3	3.93	13.91	3.90	
Synedra rumpens	2	1.16	5.42	2.70	63.12
Synedra ulna	2	2.18	9.52	2.85	3.97
Number of Species Counted		53	64	45	29
Shannon Species Diversity		4.40	4.32	3.59	2.30
Pollution Index		2.78	2.64	2.61	2.29
Siltation Index		8.88	18.30	11.71	2.70
Disturbance Index		18.92	25.77	41.59	6.36
Percent Dominant Species		19.36	25.77	41.59	**63.12**
Percent Abnormal Cells		0.29	0.29	1.04	**4.77**
Similarity Index[3]			40.80	51.96	

[1]A major diatom species accounts for 3.0% or more of the cells at one or more stations in a sample set.

[2]Pollution Tolerance Class (Lange-Bertalot 1979): 1 = most tolerant; 2 = tolerant; 3 = sensitive to organic pollution.

[3]Percent Community Similarity (Whittaker 1952) when compared to the diatom assemblage at the next upstream station.

Table 5. Modal categories for selected ecological attributes of diatom species in the Yaak River and West Fork of the Yaak River in 2003. Modal categories that represent significant departures in water quality when compared to most other sites in the sample set are given in **bold** letters.

Ecological Attribute	Yaak River Above East Fork	Yaak River at Whitetail C. G.	Yaak River at Sylvanite	West Fork Yaak River
Motility[1]	not motile	not motile	not motile	not motile
pH[2]	alkaliphilous	alkaliphilous	**circumneutral**	**circumneutral**
Salinity[2]	fresh	fresh	fresh	fresh
Nitrogen Uptake[2]	autotrophs (high organics)	autotrophs (high organics)	autotrophs (high organics)	**not classified**
Oxygen Demand[2]	continuously high	continuously high	continuously high	**not classified**
Saprobity[2]	beta-meso-saprobous	beta-meso-saprobous	beta-meso-saprobous	**not classified**
Trophic State[2]	variable	variable	variable	**oligo-mesotraphentic**

[1]Dr. R. Jan Stevenson, Michigan State University, digital communication.
[2]Van Dam et al. 1994